GRAVITY

In 1954 Dr. George Gamow, who had been specializing in the application of nuclear physics to problems in astrophysics and cosmology, made a mathematical suggestion about cell chemistry and thereby set a pattern for DNA research in genetics that has turned out to be quite valuable. This episode, in the telling of which one must mention nuclear physics, astrophysics, cosmology, mathematics, chemistry, and biology, is illustrative of Dr. Gamow's many-faceted career in science but fails to do his versatility full justice. Literary critics in both the United States and England have acclaimed him the best living interpreter of science to the layman, have delighted in his scientific fantasies and discovered poetry in his writing. To secure a reputation in either science or literature ordinarily is accounted achievement enough for one man, but Dr. Gamow has not been satisfied with both. As readers of this little book will be privileged to see, Dr. Gamow also has tackled the fine arts, democratically drawing inspiration from both the Sunday comics and the masterpieces of Sandro Botticelli. (If at first glance you do not detect the Botticelli influence in Dr. Gamow's portrait of the late Albert Einstein on page 119, at least you have assurance from the artist himself that it is there.) And in all these separate fields of creativity, Dr. Gamow has been about equally prolific.

Dr. Gamow was born on March 4, 1904, in Odes
Russia. In early youth he turned to science and spe
a year studying paleontology. This experience, he sa
later, equipped him "to tell a dinosaur from a cat
the shape of the little toes." He entered the Universi
of Leningrad, from which he received a Ph.D. degr
in 1928, and spent a year at the University
Göttingen, in Germany, on a traveling fellowship.
1928-29 he worked with Niels Bohr in Copenhage
and in 1929-30 with Ernest Rutherford at the Cave
dish Laboratory, Cambridge, England.

Dr. Gamow was twenty-four when he made his fi
major contribution to physical theory. Concurrentl
but independently, he, on the one hand, and t
American physicist E. U. Condon and the Briti
physicist R. W. Gurney, on the other, explained t
emission of alpha-particles from radioactive atoms
applying to the process the then new methods of wa
mechanics. Two years later, in 1930, he made th
successful prediction that protons would be more us
ful than alpha-particles in the experiments popular
known as "atom-smashing," and in the same year
suggested the liquid drop model for the nuclei of heav
elements. In 1929 he collaborated with R. Atkinso
and F. Houtermans in formulating the theory that th
sun's heat and light resulted from thermonuclea
processes, and his theory of the origin of chemic
elements through neutron capture dominated cosm
logical thinking at one period in the 1940s. His contr
bution to DNA theory was the suggestion that the fou
nucleotides of the DNA molecule compose a cod
whose different combinations act as templates in th
organization of the various amino acid molecules.

Dr. Gamow's personal characteristics are almost a
formidable as his creative achievements. A giant, si
feet three and well over 225 pounds, he is given t

puckish humor, as readers of his *Mr. Tompkins* fantasies well know. When he and his student, R. Alpher, signed their names to the preliminary calculations of their paper, *The Origin of Chemical Elements,* in 1948, Gamow commented, "Something is missing," and, crediting Hans Bethe *in absentia,* made the signature "Alpher, Bethe and Gamow." He speaks six languages and is a frequent and popular lecturer with a heavily accented delivery that moved a friend to observe that the six languages were all different dialects of one language—"Gamovian."

His ability as a linguist, however accented, reflects the ground he has covered in his professional career. After his studies with Bohr and Rutherford, he returned to Russia as Master in Research at the Academy of Sciences in Leningrad but left his native land for good in 1933. He lectured in Paris and London, at the University of Michigan summer school, and then joined the faculty of George Washington University, Washington, D.C., where he was professor of physics from 1934 to 1956. He became a United States citizen in 1940 and acted as a Navy, Army, Air Force and Atomic Energy Commission consultant during and after World War II. Since 1956 he has been on the faculty of the University of Colorado, Boulder.

Dr. Gamow has written many technical papers and one technical book, *Atomic Nucleus* (Oxford University Press, 1931, revised 1937 and 1949). His popular writing includes numerous *Scientific American* articles and the following books:

Mr. Tompkins in Wonderland, Cambridge University Press, 1939

Mr. Tompkins Explores the Atom, Cambridge University Press, 1943

Mr. Tompkins Learns the Facts of Life, Cambrid University Press, 1953
Atomic Energy in Cosmic and Human Life, Can bridge University Press, 1945
The Birth and Death of the Sun, Viking Press, 194
Biography of the Earth, Viking Press, 1943
One, Two, Three . . . Infinity, Viking Press, 1947
Creation of the Universe, Viking Press, 1952
Puzzle-Math (with M. Stern), Viking Press, 195
The Moon, H. Schuman, 1953
Matter, Earth and Sky, Prentice Hall, 1958
Physics: Foundation and Frontiers (with J. Cleve land), Prentice Hall, 1960
Atom and Its Nucleus, Prentice Hall, 1961
Biography of Physics, Harper and Brothers, 1961

He took up illustrating for the second *Mr. Tompkin* book when World War II interrupted communicatio between him and the English artist who had worke with him on the earlier book of the series. In 1956 h received the Kalinga Prize from UNESCO for h popular interpretations of science for lay readers.

Dr. Gamow was a member of the Academy o Science of the U.S.S.R. until, as he says, he was "fire after leaving Russia." He is a member of the Roy Danish Academy of Sciences and the National Academ of Sciences of the United States.

GRAVITY

GEORGE GAMOW

University of Colorado

Illustrations by the Author

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1962

TYPOGRAPHY BY SUSAN SIEN

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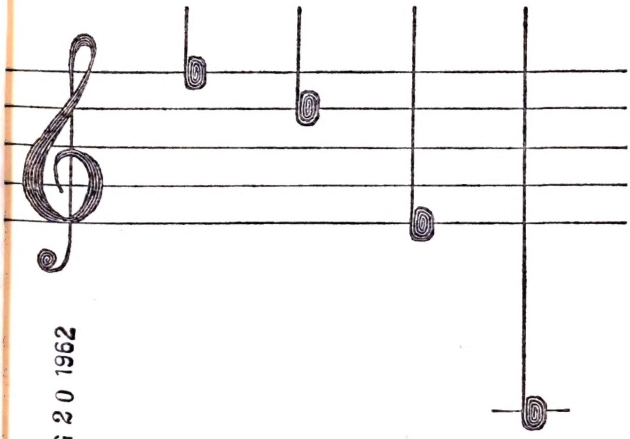
To
QUIGG NEWTON
who reads all my books



THE SCIENCE STUDY SERIES

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The Series, which now offers topics in all the sciences and their applications, had its beginning in a project to revise the secondary schools' physics curriculum. At the Massachusetts Institute of Technology during 1956 a group of physicists, high school teachers, journalists, apparatus designers, film producers, and other specialists organized the Physical Science Study Committee, now operating as a part of Educational Services Incorporated, Watertown, Massachusetts. They pooled their knowledge and experience toward the design and crea-

tion of aids to the learning of physics. Initially their effort was supported by the National Science Foundation, which has continued to aid the program. The Ford Foundation, the Fund for the Advancement of Education, and the Alfred P. Sloan Foundation have also given support. The Committee has created a textbook, an extensive film series, a laboratory guide, especially designed apparatus, and a teacher's source book.

The Series is guided by a Board of Editors, consisting of Bruce F. Kingsbury, Managing Editor; John H. Durston, General Editor; Paul F. Brandwein, the Conservation Foundation and Harcourt, Brace & World, Inc.; Francis L. Friedman, Massachusetts Institute of Technology; Samuel A. Goudsmit, Brookhaven National Laboratory; Philippe LeCorbeiller, Harvard University; Gerard Piel, *Scientific American;* and Herbert S. Zim, Simon and Schuster, Inc.

PREFACE

Gravity rules the Universe. It holds together the one hundred billion stars of our Milky Way; it makes the Earth revolve around the Sun and the Moon around the Earth; it makes ripened apples and disabled airplanes fall to the ground. There are three great names in the history of man's understanding of gravity: Galileo Galilei, who was the first to study in detail the process of free and restricted fall; Isaac Newton, who first had the idea of gravity as a universal force; and Albert Einstein, who said that gravity is nothing but the curvature of the four-dimensional space-time continuum.

In this book we shall go through all three stages of the development, devoting one chapter to Galileo's pioneering work, six chapters to Newton's ideas and their subsequent development, one chapter to Einstein, and one chapter to post-Einsteinian speculations concerning the relation between gravity and other physical phenomena. The emphasis on the "classics" in this outline grows from the fact that the theory of universal gravity *is* a classical theory. It is very probable that there is a hidden relation between gravity on the one hand and the electromagnetic field and material particles on the other, but nobody is prepared today to say what kind of relation it is. And there is no way of foretelling how soon any further important progress will be made in this direction.

Considering the "classical" part of the theory of gravitation, the author had to make an important decision about the use of mathematics. When Newton first conceived the idea of Universal Gravity, mathematics was not yet developed to a degree that could permit him to follow all the astronomical consequences of his ideas. Thus Newton had to develop his own mathematical system, now known as the differential and integral calculus, largely in order to answer the problems raised by his theory of universal gravitation. Therefore it seems reasonable, and not only from the historical point of view, to include in this book a discussion of the elementary principles of calculus, a decision which accounts for a rather large number of mathematical formulas in the third chapter. The reader who has the grit to concentrate on that chapter will certainly profit by it as a basis for his further study of physics. On the other hand, those who are frightened by mathematical formulas can skip that chapter without much damage to a general understanding of the subject. But if you want to learn physics, *please do try* to understand Chapter 3!

George Gamow

University of Colorado
January 13, 1961

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Chapter 1

HOW THINGS FALL

The notion of "up" and "down" dates back to time immemorial, and the statement that "everything that goes up must come down" could have been coined by a Neanderthal man. In olden times, when it was believed that the world was flat, "up" was the direction to Heaven, the abode of the gods, while "down" was the direction to the Underworld. Everything which was not divine had a natural tendency to fall down, and a fallen angel from Heaven above would inevitably finish in Hell below. And, although great astronomers of ancient Greece, like Eratosthenes and Aristarchus, presented the most persuasive arguments that the Earth was round, the notion of absolute up-and-down directions in space persisted through the Middle Ages and was used to ridicule the idea that the Earth could be spherical. Indeed, it was argued that if the Earth were round, then the antipodes, the people living on the opposite side of the globe, would fall off the Earth into empty space below, and, far worse, all ocean water would pour off the Earth in the same direction.

When the sphericity of the Earth was finally established in the eyes of everyone by Magellan's round-the-world trip, the notion of up-and-down as an absolute direction in space had to be modified. The terrestrial globe was considered to be resting at the center of the

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